

# **Final Report: Liquid- Phase Methanol (LPMEOH™) Demonstration Project — Light-Duty Flexible- Fueled Vehicle Demonstration**

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ARCADIS Geraghty & Miller  
Project No. SJ007315

16 April 1999

## **PREPARED FOR**

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Methanol (LPMEOH™)  
Demonstration Project —  
Light-Duty Flexible-Fueled  
Vehicle Demonstration**

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## **1. INTRODUCTION**

Since 1990, ARCADIS Geraghty & Miller (formerly Acurex Environmental Corporation) has owned one or more flexible-fuel (FFV) automobiles to serve as company vehicles for staff use, in lieu of personal vehicles, for company business-related transportation. FFVs are capable of operating with any combination of methanol-based transportation fuel (M85) and regular unleaded gasoline (RUL) as engine fuel. The current ARCADIS Geraghty & Miller FFV is a 1996 Ford Taurus, equipped with Ford's V6 3.0 flexible-fuel engine. This engine and model of automobile have an extensive record of routine use using M85 fuel. In this project, the vehicle performance and emissions when fueled with an M85 fuel prepared from liquid-phase methanol (LPMEOH™) were compared to those when fueled with standard M85.

## **2. PROJECT APPROACH**

The objective of this project was to demonstrate that LMPEOH™-based M85 is an acceptable fuel for light-duty vehicle use. In the project, the ARCADIS Geraghty & Miller FFV was operated for a total of 3,206 miles on M85 fuel dispensed from one of 21 service station locations in Northern California. It was also operated for a total of 3,479 miles exclusively on M85 fuel prepared using LPMEOH™. The periods of standard M85 fuel operation were:

- September 1997 to February 1998
- December 1998 to January 1999

LPMEOH™-based M85 operation occurred:

- May 1998 to September 1998

Fuel economy throughout all periods of operation was tracked continuously with data recorded in the vehicle log book and separate manually-recorded data collection tools.

During LPMEOH™-based M85 operation, the M85 fuel was prepared by ARCADIS Geraghty & Miller personnel by combining appropriate volumes of LPMEOH™ supplied by Air Products and Chemicals, Inc. (APCI) with RUL purchased locally. The blend was prepared by mixing 46.75 gallons of LPMEOH™ with 8.25 gallons of RUL to yield 55 gallons of M85 fuel.

The break in the standard M85 operations period noted above occurred because, during February and March 1998, local M85 dispensing stations were not in operation on a routine basis. It was decided to switch fuels to the LPMEOH™-based M85 because ARCADIS Geraghty & Miller personnel prepared it. Thus, a local supply of this fuel was guaranteed. After the desired mileage had been accumulated using the LPMEOH™-based fuel, the vehicle was returned to operation on standard M85 fuel in order to accumulate the desired remaining mileage. By this time, the earlier problems experienced by local M85 dispensing stations had been resolved.

Near the end of the initial standard M85 operating period, and again after about 1,200 miles of operation fueled with LPMEOH™-based M85, the vehicle was subjected to exhaust emissions testing. The emissions tests were performed on the chassis dynamometer at the Clean Air Vehicle Technology Center (CAVTC) in Hayward, California. For the emissions tests, the vehicle was run through the U.S. EPA Federal Test Procedure (FTP) Urban Driving Cycle. Vehicle emissions of total hydrocarbons (THC), carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>), carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nonmethane hydrocarbons (NMHC), methanol, and formaldehyde were measured.

This report documents project results.

### 3. DEMONSTRATION RESULTS

#### 3.1 Fuel Economy

Table 1 summarizes vehicle fuel economy (miles per gallon [mpg] fuel) over the demonstration test program. Fuel economy calculation spreadsheets are included in Appendix A. As shown in Table 1, cumulative fuel economy was 16.4 mpg on LPMEOH™-based M85 fuel, compared to 15.9 mpg on standard M85 fuel. The vehicle experienced nominally the same drive cycles over the test periods, so the fuel economy data in Table 1 should be relatively comparable. Indeed, fuel economy with both fuels was comparable, though the LPMEOH™ fuel gave slightly better economy.

**Table 1. Comparison of fuel economy for each fuel and data source**

<b>Fuel</b>	<b>In-Use Demonstration (mi/gal)</b>	<b>FTP Test Cycle (mi/gal)</b>
Standard M85	15.9	16.9
LPMEOH™-based M85	16.4	16.3

As a comparison, Table 1 also shows fuel economy estimates provided by CAVTC during the emissions testing periods. Here, fuel economy was 16.3 mpg when fueled with LPMEOH™-based M85 compared to 16.9 mpg on standard M85 fuel. These two values are, again, quite comparable.

#### 3.2 Emissions

Table 2 summarizes the results of the exhaust emissions tests performed with the two test fuels. The emissions test reports from CAVTC are presented in Appendix B. As shown in Table 2, the LPMEOH™-based M85 resulted in higher emissions of THC, CO, CO<sub>2</sub>, CH<sub>4</sub>,

methanol and formaldehyde, but lower emissions of NO<sub>x</sub> and NMHC. Except for methanol and formaldehyde, however, the emission differences were small.

Table 2 also notes the California emission standard for the exhaust pollutants that the State regulates. As indicated, the vehicle met the emission standards for CO, NO<sub>x</sub>, and NMHC with both the standard and the LPMEOH<sup>TM</sup>-based M85 fuels. However, the vehicle failed the formaldehyde standard with both fuels.

**Table 2. Comparison of exhaust emissions for each fuel and pollutant**

	Pollutant (g/mi)							
Fuel	THC	CO	NO <sub>x</sub>	CO <sub>2</sub>	CH <sub>4</sub>	NMHC	Methanol	Formaldehyde
Standard M85	0.093	0.867	0.138	334.4	<0.001	0.120	0.143	0.0194
LPMEOH <sup>TM</sup> -based M85	0.132	0.923	0.121	345.9	0.011	0.118	0.252	0.0337
California emission standard	—	3.4	0.4	—	—	0.25	—	0.015

Table 3 shows data on formaldehyde emissions from two model FFVs tested by the National Renewable Energy Laboratory (NREL) (Reference 1). The data show that the 1993 Plymouth Spirit, in tests of 21 vehicles, had formaldehyde emissions well within compliance with the California emission standard. However, emissions from the 1995 Dodge Intrepid, in tests of 16 vehicles, did not meet the standard. Furthermore, formaldehyde emissions from the Intrepid and from the Spirit tested at one laboratory increased as vehicle mileage increased. The final average vehicle mileage was 14,332 for the Intrepids tested, and 24,240 for the Spirits tested by the laboratory showing the formaldehyde increase. The ARCADIS Geraghty & Miller 1996 Taurus had 30,633 accumulated miles when tested with standard M85, and 32,013 accumulated miles when tested with LPMEOH<sup>TM</sup>-based M85. Based on the data in Table 3, having

formaldehyde emissions greater than 0.015 g/mi after having accumulated over 30,000 miles of operation would not be unexpected. Why emissions with LPMEOH™ fuel were greater than with standard M85 is a matter for speculation.

**Table 3. Formaldehyde emissions from other FFVs (Reference 1)**

Vehicle	Testing Laboratory ID	Test Round	Number of Vehicles Tested	Average Vehicle Mileage	Formaldehyde Emissions (g/mi)
1995 Intrepid	1	1	16	5,128	16.0 ±2.1
		2	16	14,332	17.6 ±2.3
1993 Spirit	1	1	21	8,803	12.7 ±2.7
		2	21	17,078	12.4 ±2.7
1993 Spirit	3	1	21	14,030	9.1 ±2.1
		2	21	24,240	10.4 ±2.3

#### **4. DEMONSTRATION TEST CONCLUSIONS**

Results of the test program confirm that LPMEOH™ represents an acceptable methanol base for use in preparing M85 to be used in flexible-fueled light-duty vehicles. Both in-use and chassis dynamometer test cycle fuel economy in the test vehicle fueled with LPMEOH™-based M85 were essentially the same as those with operation on standard M85. Vehicle exhaust emissions of THC, CO, NO<sub>x</sub>, methane, and NMHC were comparable with both fuels; and those of CO, NO<sub>x</sub>, and NMHC met the California emission standards with both fuels. Operation with the LPMEOH™-based M85 resulted in measurably higher emissions of methanol and formaldehyde. Higher methanol emissions should not be considered of any concern, however, as methanol emissions are not currently, or forecasted to be, regulated. Formaldehyde emissions exceeded the California emission standard with both fuels. However, based on data obtained by



NREL, FFVs having formaldehyde emissions above the California emission standard is not uncommon.

## **5. REFERENCE**

1. Personal communication, Kenneth Kelly, National Renewable Energy Laboratory, Golden, Colorado, January 1999.

**APPENDIX A**  
**FUEL ECONOMY CALCULATION SPREADSHEETS**

**FFV Mileage Log  
Standard M85**

Refuel Date	Odometer	Fuel Gallons		Miles		MPG	
		This Refuel	Cumulative	This Refuel	Cumulative	This Refuel	Cumulative
17-Sep-97	21,753	-					
18-Sep-97	22,037	15.5	15.5	284	284	18.3	18.3
19-Sep-97	22,172	8.0	23.5	135	419	16.9	17.8
23-Sep-97	22,307	11.8	35.3	135	554	11.4	15.7
25-Sep-97	22,417	9.4	44.7	110	664	11.7	14.9
30-Sep-97	22,597	8.0	52.7	180	844	22.5	16.0
3-Oct-97	22,816	18.0	70.7	219	1,063	12.2	15.0
20-Oct-97	23,109	19.0	89.7	293	1,356	15.4	15.1
22-Oct-97	23,296	7.9	97.6	187	1,543	23.7	15.8
28-Oct-97	23,561	15.1	112.7	265	1,808	17.5	16.0
MAINTENANCE INTERRUPTION							
23-Feb-98	27,713	-	112.7	-	1,808		16.0
24-Feb-98	27,964	8.7	121.4	251	2,059	28.9	17.0
26-Feb-98	28,064	12.0	133.4	100	2,159	8.3	16.2
CAVTC TESTING							
DIFFICULTY OBTAINING M85, SWITCH TO LPMEOH™ M85							
RETURN TO STANDARD M85							
17-Dec-98	36,558	-	133.4		2,159		16.2
18-Dec-98	36,727	9.1	142.5	169	2,328	18.6	16.3
19-Dec-98	36,839	7.7	150.2	112	2,440	14.5	16.2
4-Jan-99	37,015	15.1	165.3	176	2,616	11.7	15.8
5-Jan-99	37,158	8.8	174.1	143	2,759	16.3	15.8
5-Jan-99	37,287	6.9	181.0	129	2,888	18.7	16.0
6-Jan-99	37,468	12.4	193.4	181	3,069	14.6	15.9
7-Jan-99	37,605	8.0	201.4	137	3,206	17.1	15.9

FFV MileageLog  
LPMEOH™ M85[illegible]

**APPENDIX B**  
**EMISSION TEST REPORTS**

## **APPENDIX B-1**

### **STANDARD M85 FUEL**

## **APPENDIX B-2**

### **LPMEOH™-BASED M85 FUEL**